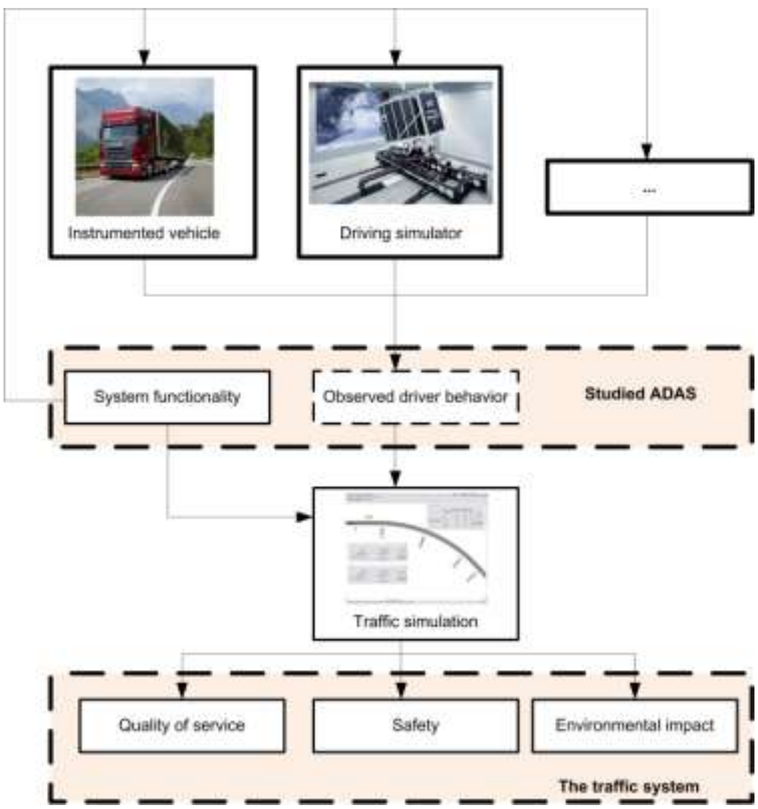
DEPEND –
Development of Evaluation and research Platform for ENvironmental Driver support



Project within Efficient and Connected Transport systems
Efficient and Connected Transport systems

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Content

1. Executive summary

The aim of the project was to develop an evaluation platform for environmental driver support systems. This was done by combining tools and models for evaluating driver behaviour (driving simulators, field tests, interviews and focus groups), evaluation of traffic performance (traffic simulation) and evaluation of environmental impacts (fuel- and emission models). The developed platform has been applied for evaluation of a support system for eco-driving.

The project has been a cooperation between Scania CV AB, The Swedish National Road and Transport Research Institute (VTI),and Intelligent Transport Systems and Logistics (University of Linköping). It has contributed with knowledge within the following areas:

- Integration of vehicle models and driver support systems in traffic simulation models
- How traffic simulation models can be designed and adapted to be able to consider fuel saving ADAS (Advanced Driver Assistance Systems) and the change of driver behaviour they might induce.
- How traffic simulation models can be designed and adapted to generate driving sequences that can be used in fuel- and emission models
- How driving simulators, field tests, traffic simulation models together with fuel- and emission models can be used in the research and evaluation process in the development of fuel saving ADAS.

The project has both resulted in a framework for combining simulation models of driving behaviour, driver support systems, powertrain and traffic; and an evaluation of a specific driver assistance system with the aim to minimise fuel consumption for heavy vehicles. The developed framework for combining traffic simulation models with simulation models for support systems and powertrain have been further developed and applied within the EC FP7 project ecoDriver.

2. Background

The development of onboard driver support systems has until now focused mainly on safety. However, during the last few years the development of environmental driver support systems has increased. The effect of such systems has historically only been measured on a vehicle individual level. A result from these evaluations can be how much fuel saving a specific assistance system can achieve on a certain vehicle individual compared to not having this system. It is however important to also consider the effect of support systems from a larger traffic environment perspective in order to minimize sub-optimization. It is for example not desired that the actions taken by a fuel saving ADAS affects other vehicles negatively from a fuel consumption perspective. If these effects of the support system can be studied early through traffic simulation this can be taken into consideration when developing such functions. By doing so, positive effects both from environmental, economic as well as driver acceptance perspective can be gained.

3. Objective

The objective of the project has been to develop a research and evaluation platform for environmental driver support systems. Traditional methods for using traffic simulations have been connected with models and tools for driver behaviour studies, traffic simulations as well as fuel- and emission studies. The research platform has then been applied on an environmental driver assistance system that uses the topography ahead of the vehicle to adapt the speed in a fuel efficient way. The key research areas of the project were:

- How can traffic simulation models be designed and developed in order to consider fuel saving ADAS and any change in driver behaviour they might induce?
- How can traffic simulation models be designed and developed in order to produce driving sequences that can be used in fuel- and emission models?
- How can driving simulators, field tests, traffic simulation models together with fuel- and emission models be used in the research and development process for fuel saving ADAS?
- Which potential and driver acceptance do fuel saving ADAS that actively controls the vehicles in a fuel efficient way have?

4. Project realization

The project has partially been conducted as research studies with supervision and cooperation between researchers at University of Linköping, VTI and Scania. The project was divided into two working packages that partially has been conducted simultaneously:

1. Development of the research and evaluation platform
2. Test and validation of the research and evaluation platform

Working package 1

- Development of methods for connecting a traffic simulation model with a fuel- and emission model.
- Enhancing the traffic simulation model to complying with the accuracy of the driving sequences required by the fuel- and emission model.
- Enhancing the traffic simulation model to be able to consider any change in driver behaviour the system might induce.
- Realization of validation object in terms of environmental driver assistance system as well as vehicle modelling.

Working package 2

- Implementation of validation object into traffic simulation model, driving simulator and instrumented test platform.
- Planning and execution of driving simulator studies
- Planning and execution of traffic simulation studies, including fuel-, energy- and emissions calculation. This also included tests of different penetration levels of the support system in order to see the effects on the traffic system.
- Validation of driving simulation studies through field test.
- Evaluation of the developed research and evaluation platform.

5. Results and deliverables

The main result of the project is the framework developed for evaluations of effects of fuel saving ADAS on both vehicle individuals as well as on a traffic system level. Figure 1 gives an overview over the framework. The driver assistance system's functionality has to be integrated/implemented into the tool used to study the behaviour of individual drivers and also into the traffic simulation model used to study the driver assistance system's effect on the traffic system. Based on studies in a driving simulator and/or instrumented test vehicles a driver model that models the drivers' interaction with the driver assistance system, e.g. when the driver switches the system on and off, possible changes in desired set speed, etc. is developed.

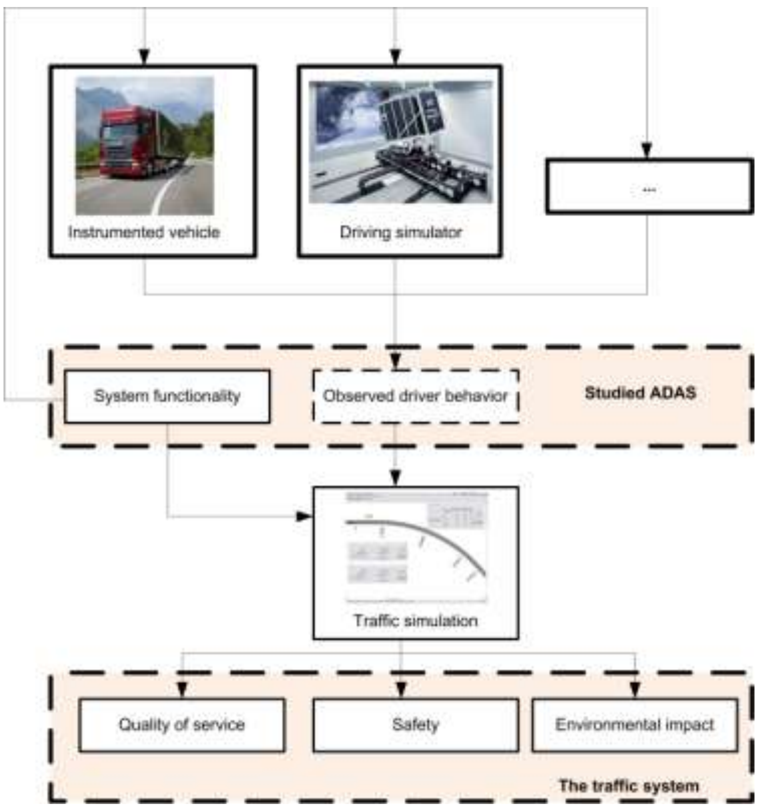

Figure 1 Overview of the framework used for evaluating fuel saving ADAS

In this project focus is on fuel saving ADAS, which normally includes calculations of fuel consumption. These calculations require that also the vehicle's powertrain is simulated. Figure 2 shows how the driver assistance system and powertrain simulation can be integrated with a traffic simulation model. In the project the concept has been tested with the system Look Ahead Cruise Control (LACC), which is a fuel minimizing cruise control. LACC has been integrated with the traffic simulation models Aimsun and Vissim. The advantages with the concept is that the driver assistance system's functionality does not have to be simplified, but can be the same implementation used in vehicle simulations or in real vehicles. Another advantage is that the details of the driver assistance system can be kept classified by keeping the implementation in a “black box”, here in the shape of a DLL (Dynamic Linked Library). The DLL has been connected to the traffic simulation models through their Application Program Interface (API). For each time-step in the traffic simulation the developed driver model is used to determine if the driver wants to switch the system on or off. The individual vehicles’ position is fetched from the traffic simulation model through its API and is transmitted to the vehicle simulation model. The vehicle simulation model then updates its vehicle speed depending on the state of the cruise control. Finally the resulting speed and acceleration is fed back to the traffic simulation model.

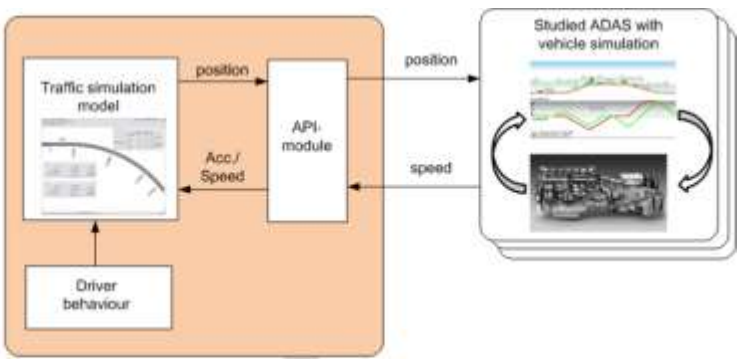

Figure 2 Schematic figure of the interface for the interconnection between a traffic simulation model and a vehicle model equipped with ADAS-functionality.

The driver model was developed based on driver simulation studies, field test studies and focus group studies with the drivers from these tests. The overall results can be summarized as

- Driving with LACC results in a reduced fuel consumption
- Driving with LACC results in a slightly reduced average speed
- The reduce in fuel consumption exceeds the reduction that comes from reduced average speed
- The reduced average speed is not compensated by the driver by increased set speed
- The drivers does not deactivate LACC more often compared to when driving when conventional cruise control, the results on the contrary indicate and increased use of LACC.
- The drivers deactivate LACC when approaching a slower moving vehicle and overtaking is not possible
- The drivers use LACC whenever possible, i.e. when traffic flow allows it.
- During overtaking, the drivers sometimes overrides LACC with the accelerator pedal to allow for faster overtaking.

Based on these results, a driver model was developed. The driver model was then implemented in the traffic simulation model VISSIM using its API. To test the evaluation platform and to study if the effects of LACC is dependent on penetration level of the system, traffic flow, etc., traffic simulation studies were performed on a number of scenarios. Figure 3 and 4 illustrates examples of fuel consumption and portion of the distance travelled with LACC activated for different penetration levels and traffic flows on a dual lane motorway. The figures clearly show that the fuel consumption for LACC is lower compared to a vehicle that only uses conventional cruise control (CC). An increased traffic flow reduces how often the drivers can use the cruise control which results in an increased fuel consumption as a consequence. The reason for this is that the drivers more frequently manually have to act on a preceding vehicle.

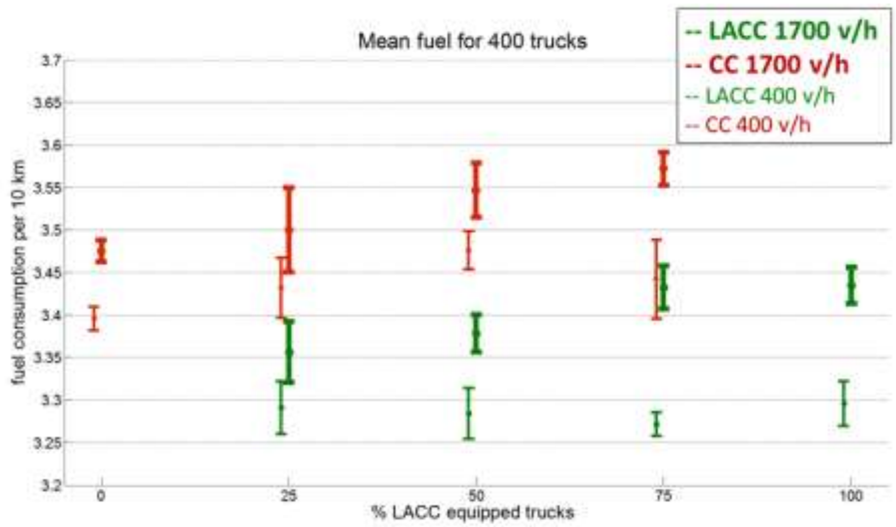

Figure 3 Average fuel consumption per 10km for vehicles with CC and LACC. Two different levels of traffic flow and five different distributions between CC and LACC equipped vehicles have been studied

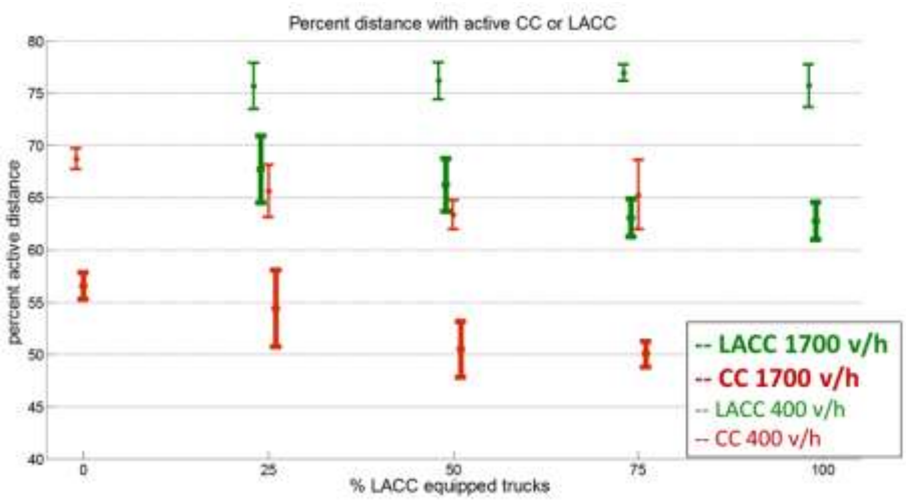

Figure 4 Average distance for which the different cruise controls have been active. Two different levels of traffic flow and five different distributions between CC and LACC equipped vehicles have been studied

5.1 Delivery to FFI-goals

- The project contributes to fulfilling the goals of the FFI Transport Efficiency program of reducing emission, reduction of CO_2, increased competitiveness for Swedish vehicle industry, increased cooperation with national research programs and the research area in general.
- The project is in line with the FFI Transport efficiency program strategy. The project contribute for example to

  > "a well working and established transport arena where industry, agencies, institutes and universities develops new forms of collaboration (e.g. for potential estimations, methods, analysis, solutions, field test and implementation of solutions)." (page 7 in the program description of Transport Efficiency, 2009)

- The project deals with two central research areas with large potential which are pointed out in the FFI program description:

  > "Transport demand analysis and simulation models for more effective development and evaluation of new transport concepts.", and
  > "the drivers role and work environment in future transport systems"

- The project contributes to the Swedish vehicle industry's possibilities for competiveness and knowledge based production by enhanced possibilities for evaluation of driver support systems.
- The project carried out industry relevant development tasks by developing the evaluation platform.
- The project lead to enhanced industrial knowledge and competence by increased understanding on drivers' needs and cognitive capacity.
- The project contributes to production improvements by the development of enhanced tools for evaluations of driver support systems and the possibilities to conduct evaluations early in the development process, this in order to ensure that resources are spent on the support systems with the highest potential.
- The project have had close interaction and cooperation with the innovation and research centres for human-machine-interaction and driving simulation ViP and for traffic analysis and traffic modelling CTR.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The project results have been disseminated through presentation at a number of national and international conferences

- "Development of Evaluation and research Platform for ENvironmental Driver support", PhD conference ITN, Norrköping, 2012
- "Development of Evaluation and research Platform for ENvironmental Driver support", CTR Stockholm 2013
- "An evaluation of Environmental Driver Support System using interacted traffic and vehicle simulation", IEEE Haag 2013
- "Evaluation of an Environmental Driver Support System using interacted traffic and vehicle simulation", PhD conference ITN Norrköping, 2013
- " An evaluation of an Environmental Driver Support System using interacted traffic and vehicle simulation", NKT October Göteborg 2013
- "Driving behavior model in a simulation based evaluation approach for Advanced Driver Assistance Systems", Transport Forum 2014
- "Driving behavior model in a simulation based evaluation approach for Look Ahead Cruise Control", NKT October Norrköping 2014
- "Driving behavior model in a simulation based evaluation approach for look ahead cruise control", Transport Forum 2015

The project has also been disseminated through a Swedish article with the title ”Plattform ska effektivisera utvärdering av miljörelaterade förarstöd" in VTI aktuellt nr 2 2011.

6.2 Publications

Hjälmdahl, M och P. Henriksson, 2012, Utvärdering av användarnas upplevelse av LACC, arbetsrapport, VTI, Linköping

Olstam, J. och R. Elyasi-Pour (2013). "Combining traffic and vehicle simulation for enhanced evaluations of powertrain related ADAS for trucks", In proceedings of IEEE-ITSC 2013, 7th October 2013 through 9 October 2013, Hague.

7. Conclusions and future research

In this project an evaluation platform for environmental driver support system has been developed. The platform has been tested and verified by applying a fuel minimizing cruise control to it. By combining tools for studies of individual driver behaviors, traffic systems and environmental effects it has been made possible to study the effect of a specific driver assistance system on an individual level as well as on a traffic system level. The platform has already been used for further evaluation of other assistance systems for fuel efficient driving in the project ecoDriver (www.ecodriver-project.eu).

Vehicle simulation models are rarely designed for connecting to traffic simulation models. Therefore several simplifications have been made when integrating the one used in this project. The interface between such models would gain much from further standardization in order to make it easier to make these kinds of integrations easier in the future.

Using field test data for evaluating driver models for traffic simulation proved to be more difficult than expected. The main obstacle was that crucial information about the traffic situation around the vehicle is often missing. Using a radar it is possible to gather information about the vehicle in front of the ego vehicle and sometimes also from vehicles in adjacent lanes. This information is however often not enough to explain why the driver acts in a certain way in a specific situation. This kind of data is available in driving simulators. The problem here is instead that the surrounding vehicles are simulated according to data models and depending on how the simulation is setup there is a risk that the wrong situations are studied or that the result depends on the simulation of surrounding vehicles. Hence, there is a need for further developing and validating the simulation of surrounding vehicles in driving simulation and also further develop methods for gathering information about such vehicles in field tests.

8. Participating parties and contact person

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